COMPARATIVE STUDY ON INDOOR FUNGI GROWTH INCORPORATED WITH DIFFERENT ANTIFUNGAL AND WALL FINISHINGS

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Special Dedication to my beloved family and friends,
for their love, support
and care me.

And

Special Thanks to my lecturers, my supervisor
for all their supports and care.

Sincerely,
Menega Subramaniam

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ABSTRACT

Indoor air quality is important to the health and comfort of building occupants. There are many sources of pollutants that can be found in the building. One of the sources of pollutants is fungus. Fungi are present almost everywhere in indoor and outdoor environments. Building materials supporting fungal growth must be remediated as rapidly as possible in order to ensure a healthy environment. The goal of this study is to compare the growth of indoor fungal by using three different antifungals such as potassium sorbate, zinc salicylate and calcium benzoate. The indoor fungi were isolated from selected room at Faculty of Civil and Environmental Engineering (FKAAS). The objective is to enumerate the growth of indoor fungal after incorporate with antifungal at different types of wall finishes and evaluate its efficiency. This research was done on three main substrates which are wood, plasterboard and concrete. These main materials were each coated with four types of coating which are thin wallpaper, thick wallpaper, glycerol based paint and acrylic paint. The growth rate was monitored as all the materials was applied with the antifungal. The antifungal has reduced the growth rate of the fungus but depending on the type of material and coating that is used. Results shows that for wood substrate, the best antifungal treatment is a mix of thick wallpaper and calcium benzoate, where the growth stops at 53% (CB 53% < PS 87% < ZS 90% < CTRL 93%). As for plasterboard substrate, thin wallpaper and potassium sorbate hinders the growth at 40% (PS 40% < ZS 73% < CB 80% < CTRL 97%) whereas for concrete substrate, acrylic paint and glycerol based paint incorporated with calcium benzoate renders the growth of fungi to stop at 0% throughout the test (Acrylic Paint = CB 0% < ZS 7% < PS 7% < CTRL 33%) and (Glycerol Based Paint = CB 0% < PS 70% < ZS 73% < CTRL 87%). Thus, the best building material would be concrete with the application of calcium benzoate for paint type of wall finishing's.

ABSTRAK

Kualiti udara dalam bangunan adalah penting untuk kesihatan dan keselesaan penghuni bangunan. Terdapat banyak sumber bahan pencemar yang terdapat di dalam bangunan. Salah satu sumber bahan pencemar adalah kulat. Kulat hampir wujud di mana-mana dalam persekitaran dalaman dan luaran. Bahan binaan yang menggalakkan pertumbuhan kulat mestilah disingkirkan secepat mungkin bagi memastikan persekitaran yang sihat. Matlamat kajian ini adalah untuk membandingkan proses penumbuhan bagi kulat tertutup dengan menggunakan tiga jenis antikulat yang berbeza seperti kalium sorbat, kalsium benzoate dan zink salisilat. Kulat diasingkan daripada bilik yang terpilih di Fakulti Kejuruteraan Awam dan Alam Sekitar (FKAAS). Objektif penyelidikan ini adalah untuk mengkaji kadar pertumbuhan kulat setelah ditambah dengan antikulat pada kemasan dinding serta menilai kecekapan ia berfungsi. Kajian ini telah dilakukan pada tiga bahan utama iaitu kayu, eternit dan konkrit. Setiap bahan-bahan utama telah disalut dengan empat jenis lapisan seperti cat yang berasaskan gliserol, cat akrilik, kertas dinding nipis dan tebal. Kadar pertumbuhan kulat dipantau bersama semua bahan-bahan yang digunakan dengan antikulat. Antikulat dapat mengurangkan kadar pertumbuhan kulat tetapi ia bergantung kepada jenis bahan dan lapisan yang digunakan. Keputusan menunjukkan bahawa rawatan antikulat yang terbaik bagi substrat kayu, adalah gabungan kertas dinding tebal dan kalsium benzoat, di mana pertumbuhan berhenti di 53% (CB 53% <PS 87% <ZS 90% <CTRL 93%). Bagi eternit substrat, kertas dinding nipis dan kalium sorbat menghalang pertumbuhan pada kadar 40% (PS 40% <ZS 73% <CB 80% <CTRL 97%) manakala bagi substrat konkrit, cat akrilik dan cat berasaskan gliserol digabungkan dengan kalsium benzoat telah menjadikan pertumbuhan kulat berhenti di 0% sepanjang ujian (Paint akrilik = CB 0% <ZS 7% <PS 7% <CTRL 33%) dan (Gliserol Berdasarkan Paint = CB 0% <PS 70% <ZS 73% <CTRL 87%). Oleh itu, bahan binaan yang terbaik ialah konkrit dengan penggunaan kalsium benzoat untuk jenis cat kemasan dinding.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%	Percentage
^0C	Degree Celsius
AP	Acrylic paint
ASHRAE	American Society for Heating, Refrigerating and Air-Conditioning Engineers
ASTMD5590-00	American Society for Testing and Materials 5590-00
BRI	Building Related Illness
C	Concrete
CB	Calcium benzoate
CONT	Control
DOSH	Department of Occupational Safety and Health
EFSA	European Food Safety Authority
EPA	United States Environmental Protection Agency
ETS	Environment Tobacco Smoke
FKAAS	Faculty of Civil and Environmental Engineering
GBP	Glycerol based paint
HVAC	Heating, Ventilation and Air Conditioning
ICOP-IAQ 2010	Industry Code of Practice on Indoor Air Quality 2010
IAQ	Indoor Air Quality
IEQ	Indoor Environment Quality
ISO 7730	International Standard Organization 7730
MEA	Malt Extracts Agar for Fungi
NIOSH	National Institute of Occupational Safety and Health
NMAM 0800	NIOSH Manual Analytical Method 0800
OSHA	Occupational Safety and Health Administration
P	Plasterboard
PS	Potassium sorbate
RH	Relative Humidity

SBS	Sick Building Syndrome
THICK	Thick wallpaper
THIN	Thin wallpaper
UTHM	Universiti Tun Hussein Onn Malaysia
VOC	Volatile Organic Compounds
WHO	World Health Organization
W	Wood
Z	Zinc salicylate

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The human health can be affected by many factors. One of the most common factors is the air that is inhaled by them. This air that surrounds the building and its exterior can be classified by using IAQ or Indoor Air Quality. This term is also a part of IEQ or Indoor Environment Quality. Poor weather condition is due to the increase in temperature day by day. Therefore, it enhance the growth of indoor fungi and the people who lives in the polluted environment suffers (Pagliano *et al*., 2016).

The US Environmental Protection Agency, (2013) stated that the indoor air pollution is a top five threats to public health, including in office, homes, other indoor area and makes existing problem worse with poor air quality. It causes harmful if not managed with properly (Joo *et al.*, 2012). The important about adsorption or desorption by building materials pollutant are incorporate as basic components of IAQ model to get some information by any influence of building materials on Indoor Air Quality (IAQ).

There are many sources of indoor air pollution. These sources include high temperature and humidity level, poor ventilation, remolding and any activities in or near a building gives impact on fresh air coming into building (Chenari, Dias Carrilho & Gameiro Da Silva, 2016). The IAQ of a space also affected by gases such as carbon monoxide, radon, volatile or organic compounds. Other than that, it is also be affected by particulates and microbial contaminants such as fungi and bacteria. The presence of these contaminants in the air, specifically fungus and its spores is not a serious issue until it is inhaled by the body. The fungus that entered the body through the respiratory system can lead to health problems or also make certain conditions much worse. Symptoms such runny nose, nasal congestion, eye irritation, cough, asthma aggravation, fatigue, headaches and difficulty in concentrating are common when exposed to the fungus.

Wall finishes are decorative elements that are applied on the surface of the wall for an accessories purpose. It brings the element of beauty and does not have any major purpose other than another protective layer for the wall while substrate are materials such as wood, plasterboard and concrete. These items are commonly used in the construction industry and can be seen on many surfaces in the interior of any houses (Kontogeorgos & Founti, 2013; Paul, Sree, & Aglan, 2010). All the items that were previously said have one common problem, it is the fungal infection on the surface of them (Tanaca *et al*., 2011; Hoang *et al*., 2010). Fungi are airborne spore spreaders that emerge during damp conditions and suitable surfaces for them to breed on. To overcome this, antifungal chemicals are used on the surfaces of the wall and its accessories.

Antifungal chemicals prevent the microbial colonization, subsequent growth and bio-deterioration of the substrate. Besides that, antifungals are eco-friendly as it is commonly used in food industry (Hwang & Huang, 2014; Heydaryinia, Veissi, & Sadadi, 2011). Antimicrobial coatings are designed to generate a surface that is easy to clean. It is also a chemical that kills or inhibit the growth of microorganisms such as bacteria, fungi, mold and algae (Roden, 2010; Tiller, 2008). Therefore, it is suggested that the application of antifungal on the wall finishing's in the building contributes to protect and prevent the bio-deterioration of the substrate and creates a healthy environment. This study has been conducted for evaluate the efficiency of antifungal such as potassium sorbate, zinc salicylate and calcium benzoate on 4 types of wall finishing which are the thin wallpaper, thick wallpaper, glycerol based paint and acrylic paint.

1.2 Problem Statement

Fungi are long known to affect the health of humans in many ways. The common ways are diseases to crop plants, decay of stored food, human tissue infections and immune system related diseases. A fungus is a heterotrophic and filamentous organism that depends on external sources of organic carbon and its cells are parasitic where they absorb nutrients through cell membranes.

Fungi use the air to spread it and therefore, it is classified as an airborne spore spreader. These spores are the actual danger of the fungi as it poses a great threat when inhaled into human body by the respiratory system. Therefore, the IAQ is a very important guide to make sure that the air inside and surrounding a space is safe. This is important as users to a normal urban home; spend almost 90% of the day in the homes.

More research need to be carried out on the IAQ issue as it leads to major health problems. High relative humidity and temperature causes to microbial growth. Malaysia's environmental factor is a perfect ground for the growth of indoor fungi. Therefore, significant research for a sustainable, long term, low cost and environmental friendly approached is needed to address and to solve the IAQ problems.

Antifungal on the other hand are the solutions to this problem but the availability of numerous antifungal in the market and the unknown effectiveness to fungal types proving to be a disadvantage. The application of antifungal as a bio resistance compound to inhibit the growth of fungi is a safe product as it was previously being used as a food preservative which was been consumed by the human beings. Yet, very few studies have remediated the indoor fungal growth using antifungals through different substrates and wall finishing's. Thus, in this study, antifungal such as potassium sorbate, zinc salicylate and calcium benzoate was used to treat the indoor fungal on 4 types of wall finishing which are the thin wallpaper, thick wallpaper, glycerol based paint and acrylic paint. Preference was given to the lecturer room, Fakulti Kejuruteraan Awam dan Alam Sekitar (FKAAS), Universiti Tun Hussein Onn Malaysia (UTHM) as it was identified with the growth of indoor fungi.

1.3 Objectives of the Study

The objectives of this study are:

i. To compare the growth of indoor fungal after incorporated with antifungal (potassium sorbate, zinc salicylate and calcium benzoate) at different types of substrates based on rating for 28 days.

ii. To evaluate the antifungal efficiency when use as a coating on substrate (wood, plasterboard and concrete) for coating bio resistance based on diameter (cm).

iii. To measure the growth rate of indoor fungal on substrate with different wall finishing (thin wallpaper, thick wallpaper, glycerol based paint and acrylic paint) that coated by antifungal and free antifungal based on percentage (%).

1.4 Scope of Study

i. The culture and harvest indoor fungi spores using biostage single–stage viable cascade impactor attached to a SKC Quick Take 30 (NAM 0800).

ii. The laboratory works for antifungal treatment for indoor fungi using potassium sorbate, zinc salicylate and calcium benzoate on thin wallpaper, thick wallpaper, glycerol based paint and acrylic paint based on rating, diameter and percentage (Belloti *et al*., 2010, ASTM D5590-00).

iii. The laboratory works without using antifungal treatment on thin wallpaper, thick wallpaper, glycerol based paint and acrylic paint based on rating, diameter and percentage (Vacher *et al*., 2010, ASTM D5590-00).

iv. The growth rate of indoor fungi was determined with the effect of antifungal and non-antifungal (Belloti *et al*., 2013, ASTM D5590-00).

1.5 Significance of Study

The primordial purpose of this study is to compare on remediation process by using different types of antifungal. Particular antifungal mentioned have a high potential to treat the indoor fungi growth (Aspergillus Niger *sp.*) as it was successfully proven in lab scale. Hence, by applying antimicrobial additives, this method reduces the building maintenance cost and saves time. This study also leads to better indoor environment.

The quality of the environment improved and variety of health effect prevented. Thus, this study serves as the basis for future plans of action. Besides that, this study which focused on antifungal as the agent in remediation process of fungi growth is an excellent source of environmental friendly. Application of antifungals, acts as an alternative by avoiding hazardous chemicals on the coating of the buildings. Quality materials which can sustain longer by adding antimicrobial coatings is an advantage for the industry too. An added point for the users and to industry is that the antifungal is cheaper, easily obtained and safe to be used and consumed. It was proven by using those selected antifungals in the food industry.

This method of application is sustainable too as much consideration given to sustainable practices due to the need and taking into consideration of present concept among engineering society. This is in line with the definition of sustainable practices, where this defined as living life in a way that uses resources in a responsible way.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes overview of related theory and previous research relevant to the study. The intention of this chapter is to give basic information about indoor environmental and air quality and it's fundamental. The material and information for this chapter has been gathered from various reference books and research papers.

2.2 Indoor Environment Quality (IEQ)

The quality of a building's environment in line with the health and well-being of people who live in particular area is referred as Indoor Environment Quality, IEQ. The effect of poor IEQ is not only on physical health of the building occupants, but also on their physiological health (Ahmed, 2007).

Basically, IEQ can be determined by many factors such as lighting, air quality and damp conditions. Dampness, cleanliness and ventilation characteristics are associated with building related symptoms (Lee *et al*., 2012). Therefore, many health related problem was occurred due to this poor environment. Wong, Mui & Hui (2008) states that thermal comfort, indoor air quality, noise level and illumination level are the four aspects to examine the Indoor Environment Quality, IEQ. Air quality and freshness, the presence of light, thermal comfort and quality of acoustic are the important factors of IEQ in healing environments, which affect occupant satisfaction (Lai *et al*., 2009; Sarbu & Sebarchievici, 2013).

Variety of contaminants whether from machines inside the buildings, dust cleaners, renovation works, water damaged building materials, carpets and furnishings, cigarette smoke, perfumes, microbial growth, insects and outdoor pollutants are the common contaminants faced by the building occupants (Parjo *et al.*, 2015). How individuals respond to indoor environment can also predicted through the indoor temperature, relative humidity and the ventilation levels of a building. Energy consumption of buildings depends significantly on the criteria used for the indoor environment (temperature, ventilation and lighting) (Sarbu & Sebarchievici, 2013). Building related symptoms could be resolved by understanding the sources of indoor environmental contaminants and by controlling them. There are 6 categories of IEQ which shown in Figure 2.1 and Table 2.1 tabulated the definition of Indoor Environmental Quality (IEQ) according to EN 15251.

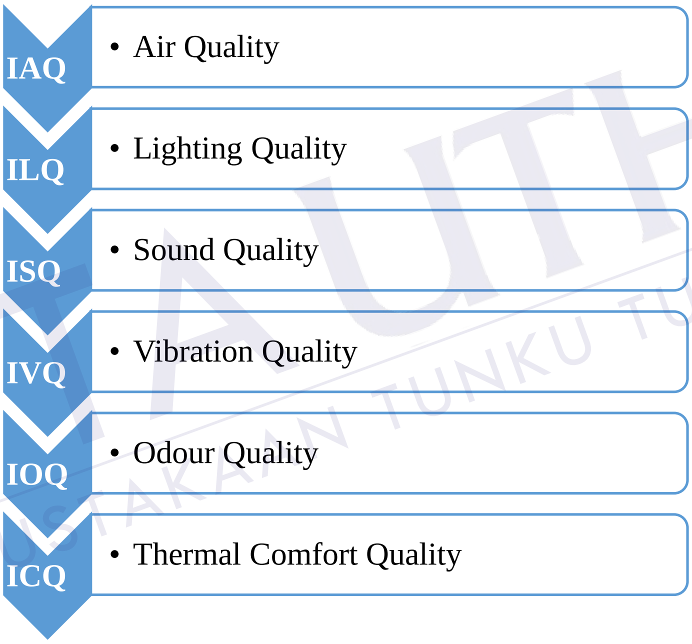

Figure 2.1: Categories of Indoor Environmental Quality (Robert, 2009)

Table 2.1 Definition of Indoor Environmental Quality (IEQ) According to EN 15251

Category	Explanation
I	High level of expectation is recommended for space occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons.
II	Normal level of expectation and should be used for new buildings and renovations.
III	An acceptable, moderate level of expectation and may be used for existing buildings.
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year.

2.3 Indoor Air Quality (IAQ)

It is defined as the air quality within and around buildings, because it is concerning the health with comfort of building occupants. The degradation of indoor air quality induced by microorganisms (molds, bacteria, fungi) is of growing concern to international health organization (Leman *et al*., 2006; Verdier *et al*., 2014). Indoor air quality is a major determinant of personal exposure to pollutants in today's world. Much time is being spent in numerous different indoor environments by people (Sarbu & Sebarchievici, 2013). Norhidayah *et. al.,* (2013) reported that people spend their lifetimes up to 80% in workplace or homes. Problems caused by microbial, especially fungal growth do exist in some new buildings (Ismail, Deros, & Leman, 2010; Er *et al.*, 2015; Parjo *et al.*, 2015). IAQ is a part of indoor environmental quality (IEQ) (Lee *et al.*, 2012). Collection of air samples, monitoring human exposure to pollutants, collection of samples on building surfaces and computer modeling of air flow inside buildings are some of the way involved in determining the IAQ.

Indoor air quality is very important because it is one of the main discomfort causing factors in a closed space. Removing this discomfort factor causes most people to feel better. Indoor environment also affects health, productivity and comfort of the occupants (Sarbu & Sebarchievici, 2013; Er *et al*., 2015). However, some pollutants cause diseases which have no symptoms immediately but will emerged later. Some examples of the diseases are cancer and respiratory problems (Kris-Etherton *et al*., 2002).

2.3.1 Elements of IAQ problems

In any home, there are many types of indoor air pollution that can occur. Some of the reasons for the pollution to happen are gas, coal and tobacco products which are common in the kitchen. Other than that, damp carpets, wood furniture's, heating and cooling systems and pesticides are also sources of pollution that affect the IAQ of a space. The unsuitable fitting materials, adhesive and furniture selection are also contributing to the sources of poor IAQ (Noraini *et al*., 2013). Mainly, the importance factor is how much of pollutant is releases and the danger level that the pollutant has. Age factor of the source and its maintenance are also important in its determination.

Elements which involved in development of indoor air quality problems are clearly shown in Table 2.2.

Table 2.2 Elements of Indoor Air Quality problems (EPA, 1991)

Elements	**Description**
Source	There is a source of contamination or discomfort indoors, outdoors or within the mechanical systems of the building.
Heating, Ventilation, and Air Conditioning (HVAC)	The HVAC system is not able to control the existing air contaminants and ensure thermal comfort (temperature and humidity conditions that are comfortable for most occupants.
Pathways	One or more pollutants pathways connect the pollutant source to the occupants and a driving force exists to move pollutants along the pathway(s).
Occupants	Building occupants are present.

2.3.2 Factor Affecting IAQ

Ventilation is a typical improving method of IAQ of buildings (Lee *et al.*, 2012). Insufficient ventilation or air circulation builds up the indoor polluted level. Therefore, many factors affect the IAQ. Indoor, outdoor and HVAC system are the major three following elements that are involved in the development of indoor air quality problems. According to Lee *et al.*, (2012) reported that one of the principal methods to mitigate IAQ problems is the ventilation, which is mainly composed of active IAQ control by heating, ventilation and air conditioning (HVAC) and passive IAQ control by natural ventilation.

The contaminants of indoor air may come within the building and also from outside of the building (WCB, 2005). The first element is indoor. Personal activities such as smoking or personal hygiene affects the indoor air quality. The use of deodorizers, cleaning materials or dust while doing the housekeeping also contributes to this factor. Indoor air quality will be affected by the emissions of volatile organic compounds given off by office equipment like photocopier machines and from the office supplies such as toners, carbonless paper products. Besides that, poor thermal and humidity comfort and huge number of occupant load do contribute to this factor.

Other factor that affects the IAQ is the outdoor. Vehicle exhaust, pollen, or industrial pollutants contaminates the outdoor air. The indoor air also polluted due to the nearby source emission especially from the garbage dumpsters, loading docks or the re-entrained exhaust from buildings. Radon, underground storage tanks or pesticides are under the group of soil gas that pollutes the air quality. Finally, another reason that enhances the poor indoor air quality is the microbial from standing water that is molds or mildew.

The HVAC system classified as one of the affecting elements of poor indoor air quality. Inadequate distribution of fresh air in ventilation system contributes to this phenomenon (Gaskin *et al.,* 2012). Unclean air filters, dust in ductwork enhance the microbiological growth in ductworks and or humidifiers. Inadequate IAQ has been tied to symptoms including headaches, fatigue, trouble concentrating, and irritation of the eyes, nose, throat, and lungs. Table 2.3 below shows the Sources of Indoor Air Contaminant according to EPA, 19911.

Table 2.3 The Sources of Indoor Air Contaminant (EPA, 1991)

Sources	Categories	Description
Outside Building	Contaminated outdoor air	Pollen, dust, fungal spores, industrial pollutants and general vehicle exhaust
	Emissions from nearby sources	Exhaust from vehicles on nearby roads or in parking lots, or garages, loading docks, odors from unsanitary debris near the outdoor air intake
	Soil gas	Radon, leakage from underground fuel tanks, contaminants from previous uses of the site (e.g: landfills) and pesticides.
	Moisture or standing water promoting excess microbial growth	Rooftops after rainfall and crawlspace
	Equipment HVAC system	Dust or dirt in ductwork or other components microbiological growth in drip pans, humidifiers, ductworks, coils improper use of biocides, sealants, and/or cleaning compounds, improper venting of combustion products and refrigerant leakage.
	Non-HVAC equipment	Emission from office equipment (volatile organis compounds, ozone), supplies (solvents, toners, ammonia), emissions from shops, labs, cleaning processes, elevator motors and other mechanical systems.
Human Activities	Personal activities	Smoking, cooking, body odors, and cosmetic odors.
	Housekeeping activities	Cleaning materials and procedures, emissions from stored supplies or trash, use deodorizers and fragrances, airborne dust or dirt (e.g: circulated by sweeping and vacuuming).

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